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The Forgiving Air: Understanding Environmental Change.

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By Richard C. J. Somerville, Berkeley: University of California Press, 1996. 196 + xiv pp., $21.95.

As I write this review, the United States vice presidential debate between Al Gore and Jack Kemp has just taken place. In his introductory remarks, rather as a joke, Gore said that if Kemp would refrain from football metaphors, he, Gore, would refrain from talking about chlorofluorocarbon abatement. To this, Kemp jokingly replied that he could not even pronounce it.

I am afraid that this situation is more than a joke. Most of our politicians are woefully ignorant of the science underlying environmental change, an area for which they bear, on our behalf, the responsibility for making decisions the consequences of which will reach far into future generations, much as will decisions about balancing the budget or keeping the social security system solvent.

Ultimately, politicians are responsible to the electorate: If the electorate is concerned about an environmental issue, the politicians will follow, as has in fact happened in this country with nuclear energy. Unfortunately, the science of global change is complicated, full not just of words that are difficult to pronounce but also of concepts that are hard to comprehend.

Enter Richard Somerville's highly readable little book, the objective of which is to convey the scientific basis of major environmental change phenomena to an audience of interested nonscientists. Somerville believes that "everyone who is interested in global-change issues can and should become familiar with the remarkable story of the science that underlies them" and that "an informed citizen of the Earth can and should be scientifically literate." Somerville holds, moreover, that scientists have an obligation to participate in the general education of educated nonscientists so that they can deal intelligently with a world in which the role of science is increasingly critical. (In the preface, Somerville notes that the book results from a course on interdisciplinary global change science that he prepared and taught to elementary and middle school teachers.) Somerville explicitly takes "all people" as the audience of this book: "No technical training or scientific background is required."

The first challenge to the author of such a book is to get people to read it--to make it sufficiently attractive that the audience will come and sufficiently readable that they will stay for the message. In this respect, I think Somerville has succeeded. He certainly livens up the book with human interest, with anecdotes such as the research project of Molina and Rowland that was turned down by funding agencies but that went on to predict stratospheric ozone depletion and win a Nobel Prize. Likewise, Somerville tries to keep the book from overly taxing the reader by minimizing mathematics and by avoiding equations altogether. Evidently for the same reason, he includes virtually no figures. The single exception is the record of David Keeling's measurements of carbon dioxide at Mauna Loa extending from 1958 to the present that demonstrates incontrovertibly the increase in carbon dioxide concentration over this period, as well as the annual fluctuations and other lesser wiggles. If one were to pick a single figure to demonstrate human influence on our atmosphere, this certainly would be the one. To my thinking, however, the lack of figures works against Somerville's objectives. Good figures, such as Keeling's, can be understood readily by nonscientists and can convey information much more powerfully than written language.

The book focuses on three "great environmental issues of our time" that have global and geopolitical implications: stratospheric ozone depletion, the greenhouse effect, and acid deposition. To the author's credit, he conveys the essence of these several phenomena and, in passing, much pertinent atmospheric science such as the Hadley circulation and fronts and the temperature structure of the atmosphere, all at a level that should be readily understandable by intelligent and motivated nonscientists. At the same time, Somerville astutely recognizes that the motivation for the nonscientist to learn about these issues will come not--as it does for the scientist--from an intrinsic fascination with science, but rather from an appreciation of the beauty and fragility of our planet. This in turn can lead to a sense of stewardship, of responsibility to protect our planet, especially because human activity is now leading to demonstrable global-scale changes in the composition of the atmosphere and to resultant adverse consequences.

Somerville openly admires the earth scientists whose measurements led to the discovery of the phenomena he discusses, "motivated only by their own curiosity and a hunch that their observations would turn out to lead to something worthwhile." High in his pantheon is Joe Farman, of the British Antarctic Survey, who discovered the Antarctic ozone hole, not only for making the discovery but also for being skeptical of his data and for repeating the measurements in successive years before publishing. Somerville likewise praises David Keeling, who has persisted in his measurements of carbon dioxide for the better part of four decades. He characterizes Keeling as an ordinary obsessive scientist, albeit a strongly motivated one.

The book is perhaps at its best in its treatment of stratospheric ozone depletion, in part because the evidence for the Antarctic ozone hole and its relation to chlorofluorocarbons (CFCs) is so strong. The discussion starts with a bit of history of the CFCs as wonder chemicals--nontoxic, nonflammable, and indestructible, with just the right physical properties for a myriad of uses. As we now know, it is just that indestructibility that allows these chemicals to persist in the atmosphere long enough to be wafted to the stratosphere, where they succumb to the harsh ultraviolet and where, by sheer chance, their photolysis products can serve to catalyze the decomposition of stratospheric ozone. Somerville does not shy away from including chemical reactions, and the discussion conveys the overall photostationary state responsible for the ozone layer and the basis for catalytic decomposition by chlorine atoms, although here and elsewhere the book is marred by errors in description of the atmospheric chemistry. (Only a small fraction of molecular oxygen [O] atoms formed in the photolysis of oxygen [[O.sub.2]] recombine; the great majority add to oxygen to form ozone [[O.sub.3]]). One only wishes there were a few choice figures such as the vertical profile of ozone, before and during the Antarctic spring, or the "smoking gun" measurements of ozone and chlorine monoxide during the Antarctic stratospheric aircraft measurement campaign.

The treatment of the greenhouse effect is likewise very successful, owing undoubtedly to the author's ability to speak authoritatively from his own research. Somerville begins with the preindustrial greenhouse effect and makes the point loud and clear that the present temperate climate of the earth derives in large part from the greenhouse effect of naturally present gases and clouds. He conveys the concept of the earth's radiation balance and of the dual role of clouds, as reflectors of solar radiation (exerting a cooling effect) and as absorbers and emitters of terrestrial thermal infrared radiation (exerting a warming effect). Somerville introduces the Stefan-Boltzmann equation (in words) and tries to convey the nature of a fourth-power dependence. Here again, a figure would help considerably. Likewise, a figure would help beyond words in conveying the spectrum of terrestrial infrared emission and the role of atmospheric absorbers. Somerville notes convincingly that the moon is the same distance from the sun as is the earth yet has a very different climate, largely because of the lack of a greenhouse atmosphere. The discussion of the natural greenhouse effect is crucial background to conveying the enhancement of the greenhouse effect resulting from anthropogenic carbon dioxide and other greenhouse gases.

Because present understanding of the climatological consequences of enhanced concentrations of greenhouse gases relies almost entirely on computer models, Somerville devotes considerable attention to the philosophy and approach of such modeling. He does a good job of conveying both, as well as of conveying the reasons for uncertainty in the model predictions. Because a cloud's radiative influence and even its very existence depend subtly on the controlling atmospheric variables, it is exceedingly difficult to model these radiative properties accurately, even in the present climate, and all the more so in a future, changed climate. Somerville does not shy away at all from the consequences of uncertainty in predictions of climate change. He concludes: "Climate modeling remains largely an unsolved problem.... We ought to take the model results, the climate scenarios of the future, seriously, but not literally." The basis for societal concern over the anthropogenic enhancement of the greenhouse effect thus rests more on a reasoning by extension based on the natural greenhouse effect than on observations or even model predictions.

The discussion of acid deposition and regional air pollution is somewhat less satisfying to me as an atmospheric chemist, perhaps in part because Somerville characterizes this problem as solved and therefore boring to atmospheric chemists. The decade of the 1980s saw intense research on the atmospheric chemistry of acid deposition, as well as on the effects of acid deposition on aquatic and terrestrial ecosystems. This research sufficiently reinforced previous understanding of the gross features of the phenomenon to convince Legislative bodies, especially the U.S. Congress, of the necessity of reducing emissions of sulfur dioxide and, to a lesser extent, nitrogen oxides--the precursors of acid deposition. There is little doubt that reduction of emissions will lead to reduction of deposition, just as there is little doubt that reduction of carbon dioxide emissions will lead to a decreased rate of accumulation of carbon dioxide in the atmosphere. Scratch the surface, however, and you find major unresolved issues of atmospheric science. There is still great uncertainty concerning even such key quantities as the fraction of emitted sulfur dioxide that is oxidized in the atmosphere to form sulfate aerosol versus that deposited to the surface as sulfur dioxide, and the mean atmospheric residence time of sulfate aerosol, as governed by the efficiency of removal in precipitation and the frequency of precipitation events. Consequently, much uncertainty remains in projections of the geographical pattern of reduced deposition that would result from a given pattern of emissions reductions--projections that are based on representing scientific understanding in computer models similar to those employed in climate research. The study of acid deposition was not abandoned by atmospheric scientists because they got bored. It was abandoned because funding for this research evaporated once legislation was passed to "solve" the acid deposition problem.

Let us look at the legislation. Emissions were to be reduced by 50%. Cynically, this could be viewed as a compromise between 100% reduction and zero reduction. Certainly the legislation was not based on detailed understanding of the atmospheric chemistry and meteorology controlling the pattern of reduction in deposition. Likewise, it is not known from the standpoint of mitigating the effects of acid deposition whether this legislated reduction is sufficient, insufficient, or overkill. And it will not be known, because the follow-up research is not being conducted, and that is because the government bureaucrats responsible for funding research no longer perceive the need for scientific study of the phenomenon, a view that unfortunately is reinforced by Somerville's statement that the problem is entirely solved. So there is an experiment going on right now, the reduction in sulfur emissions by a factor of two, that is costing billions of dollars, and virtually no one is making the observations and doing the computer modeling to test and improve our understanding of the phenomenon. Sooner or later, the issue of acid deposition will once again rear its ugly head, and we shall come to regret our abandonment of research in this area and the concomitant loss of opportunity to have improved our understanding of this phenomenon.

Ironically, there is an important connection between acid deposition and global warming, one not mentioned by Somerville. Atmospheric aerosols (small particles suspended in air, the particles that comprise urban haze), consisting largely of sulfate and nitrate, scatter solar radiation and increase the reflectivity of clouds. The increase in atmospheric loadings of these particles over the industrial period, the period over which carbon dioxide concentration has been increasing, is thought by many investigators to have exerted a cooling influence on the earth's radiation budget, opposite in sense to the warming influence of carbon dioxide and the other greenhouse gases but comparable in magnitude. The magnitude of the climate forcing by aerosols, however, is quite uncertain. The Intergovernmental Panel on Climate Change considers this the greatest uncertainty in climate forcing over the industrial period. Some investigators think that this uncertainty is so great as to preclude any meaningful empirical inference of global warming from climate change over the industrial period. Part of what makes Somerville's characterization of the atmospheric chemistry of acid deposition as a solved problem so troubling to me is that much of the uncertainty in describing the climate influence of aerosols arises from uncertainty in the atmospheric chemistry of the aerosols, Somerville's so-called solved problem. Regrettably, the knowledge required to reduce this uncertainty to the extent required for meaningful assessment of the climate influence of these aerosols will not be forthcoming without substantial research, and the perception that this problem is solved will not bring about the change in will among politicians and bureaucrats necessary to reinvigorate the research required to reduce the uncertainty.

Beyond the issues of atmospheric science discussed in the book, Somerville also treats the human activities that are responsible for the emissions, especially issues of energy use that are responsible for carbon dioxide emissions. Here, in my opinion, the book becomes somewhat dissatisfying. The discussion is often superficial and hardly quantitative. In the face of the enormous growth in world population and the First World aspirations of the Third World, which Somerville describes only too well, we are left with only vague exhortations to use renewable energy sources, to buy more fuel-efficient cars, to carpool, to live closer to work, and to walk or bike to work. There is no quantitative examination of the change in lifestyle that would be required to stabilize atmospheric carbon dioxide emissions or of the far greater change that would be required to stabilize carbon dioxide concentrations. Likewise, the nuclear option, which already has been taken by a number of countries, most notably France, is in my view too quickly dismissed by invoking the specter of terrorism and myths such as the statement that a millionth of a gram of plutonium can give you lung cancer. Reasoned quantitative understanding is required just as much in discussion of our future energy economy as it is in discussion of atmospheric science.

Despite the concerns that I note, I believe that Somerville has largely succeeded in his objective of conveying the scientific basis of major environmental change phenomena to an audience of interested nonscientists. He gives a broad overview of atmospheric science to nonspecialists but leavens it with enough human interest to keep his audience. An extensive glossary helps to reinforce the definitions that are introduced in the text. By the end of the book, the nonscientist reader will certainly have gained an appreciation of the atmospheric phenomena responsible for global change and a sense of the limits to the forgiveness of the air.

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